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(54) Title: METHOD AND APPARATUS FOR ENERGY PRODUCTION USING COLD NUCLEAR FUSION WITH A LITHIUM DEUTEROXIDE ELECTROLYTE
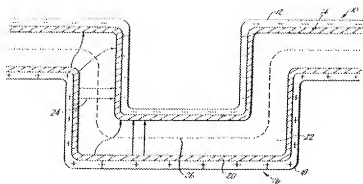
(57) Abstract

The present invention enables nuclear fusion of deuterons and lithons. A crystalline lattice (14) having octahedral interstitial sites aligned with an electrical field (24) is exposed on a first surface to a electrolytic solution of heavy water and lithium deuteroxide contained in a channel (22). Deuterium and lithium atoms from the electrolyte are absorbed into the crystalline structure where their electrons are stripped to produce deuterons and lithons, the latter retaining two electrons. Under the influence of the electric field, deuterons tunnel through the lattice and collect in interstitial sites to provide a palladium deuteride lattice (the β phase of palladium). A barrier, which may comprise an electrode (12) on which the crystalline lattice is deposited, is introduced which terminates the lattice perpendicular to the electric field to preclude further tunneling or diffusion of the deuterons from the interstitial sites adjacent the barrier. Heating of the electrolytic solution enhances the overlap of the energies of the diffusing particles with transmission resonance energy levels specific to the metal deuteride lattice and the particles diffusing through it. This promotes the diffusion of deuterons and lithons from the electrolyte into the lattice increasing the probability of fusion reactions between diffusing particles and the deuterons already in the lattice interstitial sites. Heat generated from the fusion reactions is extracted from the crystalline lattice and employed for power generation.

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10   METHOD AND APPARATUS FOR ENERGY PRODUCTION
                    USING COLD NUCLEAR FUSION
              WITH A LITHIUM DEUTEROXIDE ELECTROLYTE

Cross-Reference to Related Applications
15   This is a continuation-in-part of prior U.S. Patent
     Application Serial Number 07/352,853, filed on May 15,
     1989, in which a method and apparatus employing a
     crystalline palladium lattice for the production of energy
     using cold nuclear fusion is described in detail and
20   incorporated herein by reference.

Field of the Invention
          The present invention relates generally to production
     of power through the use of a steam turbine system
25   receiving heat energy from a nuclear fusion reactor. More
     particularly, the invention provides a
     crystalline/palladium lattice reactor aligned in an
     electric field to receive deuterons into interstitial
     lattice sites from a deuterium source. The crystalline
30   lattice is blocked perpendicular to the electric field in
     the lattice at a given depth preventing migration of
     deuterons out of the lattice. The crystalline lattice is
     immersed in a heavy water electrolyte solution containing
     lithium deuteroxide (LiOD). A heater maintains the
35   electrolyte solution at an elevated temperature to
     increase the number of transmission resonance levels
     available for deuteron and lithium diffusion in the

1   lattice. Use of a high purity of Li^6 isotopes in the
     lithium deuteroxide enhances the reactor by reducing the
     probability of tritium production. Heat energy generated
     in the fusion is conductively transferred to a liquid
5   coolant system and steam driven turbines for power
     generation.

     ## Background of the Invention
           Basic concepts for the generation of energy through
10   nuclear fusion have centered on the so-called "hot" fusion
     approach. In "hot" fusion, deuterium atoms are forced
     together under great pressure and temperature sufficient
     to provide energy to overcome the Coulomb repulsion force
     and drive together the nuclei of the deuterium atoms to
15   fuse. The result is nuclear fusion to produce an He^3
     nucleus plus a neutron or a tritium nucleus plus a proton.
     Temperatures of 10^8 degrees K are required to provide
     sufficient energy to overcome the Coulomb barrier of the
     deuterons.
20   In a palladium lattice loaded with deuterons, a β
     phase of palladium is produced which may significantly
     increase the probability for nuclear reactions between
     deuterons diffusing through the lattice and the deuterons
     fixed in the lattice producing the β phase. It has been
25   suggested by L. Turner in his letter to the editor
     published in _Physics Today_, 1989, pp. 140-141, that cold
     fusion may involve transmission resonances for deuterons
     diffusing through a periodic array of wells formed by the
     Coulomb barriers of the deuterons sitting at the
30   interstitial sites. The resonance condition of

$$\int \kappa(x) \, dx = (n + 1/2) \, \pi$$

     will provide a transmission coefficient of unity if
35   satisfied by the wave number of the particle crossing the
     potential well between two neighboring barriers where $\kappa(x)$

1   is   the   wave   number   of   the   diffusing   particle.   A
        transmission resonance condition may be hypothesized as

$$(2n + 1) \lambda/4 = L$$

5
        where n = 0, 1, 2 . . .. λ is the de Broglie wavelength
        of the diffusing deuteron and L is the width of the well
        in the array. Electron screening of the deuterons by the
        palladium lattice will make the wells shallower than
10   normal.   Transmission will, therefore, occur for a
        diffusing deuteron whenever an odd number of quarter
        wavelengths of the deBroglie waves fit into the well
        width. Bohm has noted in Quantum Theory, Prentice-Hall,
        Inc., Inglewood Cliffs, New Jersey, 1951, p. 287, that "it
15   is especially interesting that although a single high and
        thick barrier has a very small transmissivity, two such
        barriers in a row can be completely transparent for
        certain wavelengths. This barrier can be understood only
        in terms of the wave-like aspects of matter. The high
20   transmissivity arises because, for certain wavelengths,
        the reflected waves from inside interfere destructively
        with those from outside so that only a transmitted wave
        remains."
               As also shown by Bohm, the resonance condition also
25   expresses the condition for existence of metastable or
        virtual states associated with wells having barriers.
        These states are unbounded and have a relative long
        lifetime due to the fact that deBroglie waves associated
        with the deuterons reflect back and forth in the well many
30   times before the barrier is penetrated. The energies of
        these states may be found by combining the transmission
        resonance condition equation with the following well known
        relations:

35                          $E = p^2/2m$ and $\lambda = h/p,$

1   where p is the momentum of the diffusing deuteron and m
      is its mass.   Combining these equations yields the
      metastable state energies:

5                    $E_n = (2n + 1)^2 \, h^2/32m \, L^2$.

      Since these energies are based on the resonance condition
      to achieve transmission, these are also the energies for
      the transmission resonances.
10   If occupation of a metastable state is proportional
      to the Boltzmann factor:

                     $\exp \, (-E_n/kT)$,

15   where k is the Boltzmann's constant and T is the
      temperature in Kelvin, the energies may be expressed in
      terms of temperatures T_n,

                     $E_n = kT_n$.
20
      The Boltzmann factor may then be rewritten:

                     $\exp \, (-T_n/T)$.

25   Substituting for the energy E_n, we find

                     $T_n = (2n + 1)^2 h^2/32mkL^2$.

      This equation indicates the temperature relationship for
30   resonance levels associated with the widths, L, of the
      wells in the array produced by the lattice as previously
      described.
           An apparatus designed by Pons and Fleischmann has
      been reported in an article (see Fleischmann, M. and Pons,
35   S., "Electro-chemically Induced Nuclear Fusion of
      Deuterium", submitted to Journal of Analytical Chemistry,
      March 20, 1989).   The apparatus which was employed to

1   obtain the fusion reported in this paper was embodied in
     several forms. In a first embodiment, a palladium rod
     cathode and an encircling helical platinum anode were
     inserted in a heavy water (D_2O) electrolytic solution
5   connected with a potential providing a maximum current
     density of approximately 512 mA/cm^2. In an alternative
     configuration, a rectangular palladium sheet cathode was
     surrounded by a platinum sheet anode and operated in the
     heavy water electrolyte with current densities of
10   approximately 1.6 mA/cm^2. With both configurations,
     evidence of nuclear fusion was reported. However, methods
     and apparatus to obtain consistent power generation with
     controllability of the fusion reaction and necessary
     reliability are unknown.

15   Nuclear effects have also been noted by H. O.
     Menlove, M. M. Fowler, E. Garcia, A. Mayer, M. C. Miller,
     R. R. Ryan, and S. E. Jones, as noted in a presentation
     to the Workshop on Cold Fusion Phenomena, May 23 through
     25, Santa Fe, New Mexico, entitled "The Measurement of
20   Neutron Emissions from Ti + D_2 Gas". Neutron emissions
     were noted from titanium shavings pressurized with D_2 gas
     cooled to liquid nitrogen temperature and warmed to 243
     K. Similar nuclear effects were seen in the Cassacia
     experiment reported by A. DeNinno, et al., in a
25   presentation at the Workshop on Cold Fusion Phenomenon,
     May 23 through 25, Santa Fe, New Mexico, entitled "Neutron
     Emission from a Titanium Deuterium System", in which
     titanium blades were heated at 1,273 K in the presence of
     0.1 mbar of D_2 gas, followed by lowering of the
30   temperature to 773 K at 20 mbar D_2. Neutron emission was
     observed after reheating of the sample to 1,273 K. Again,
     however, methods and apparatus to obtain consistent power
     generation with controllability of the reaction present
     were not disclosed.

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1   ## Summary of the Invention

          The present invention provides a method and apparatus
     for obtaining heat energy from cold fusion. A palladium
     crystalline lattice provides a containment structure for
5   deuterons in the octagonal interstitial sites of the face
     centered cubic structure.   Deuterons with sufficient
     energy will migrate through a uniform palladium lattice
     by tunneling through the covalent bond barriers of the
     lattice.   By alignment of an electric field with the
10   <1,1,0> direction of the palladium lattice diffusion of
     the deuterons through the lattice is enhanced.   To
     preclude diffusing particles from transitioning completely
     through the lattice, a means for blocking further
     tunneling is provided.

15   In a presently preferred embodiment, the palladium
     lattice is structured as a plurality of single crystal
     rods with the <1,1,0> direction of the individual lattice
     sites in the rods perpendicular to a first surface of the
     crystal. The first surface of the crystal is exposed to
20   a source of deuterium atoms, such as a heavy water
     electrolyte solution, to provide a source of deuterons.
     The blocking member interfaces the crystalline lattice on
     another surface of the crystal perpendicular to the
     electric field to prevent tunneling of the deuterons
25   completely through the crystal. Preferably the blocking
     member is a metallic structural member. The combination
     of the palladium crystal and the metallic member may
     operate as a cathode in an electrolytic cell.

          An   electrolytic   solution   containing   lithium
30   deuteroxide (LiOD) to provide lithium ions (lithons) and
     deuterium ions (deuterons) is employed in the cell.
     Deuterons diffusing into the palladium lattice create a
     β phase   in   the   palladium   which   allows
     transmission of lithons and deuterons into the palladium
35   deuteride lattice. The lithons and deuterons react in the
     lattice in a cold fusion process producing heat energy.

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1   By employing high purity Li^6 isotopes in the lithium
         deuteroxide electrolyte, production of tritium is avoided
         thereby providing a "clean" reactor.

               Configuration of the cathode as a structural dividing
5   member allows containment of the electrolytic solution on
         the crystal surface of the cathode with circulation of a
         coolant fluid on the opposite side of the cathode to
         transport away heat generated by the fusion process in the
         lattice. A complementary anode structure of appropriate
10   materials provides a second wall for the electrolyte
         container. Sealing between the edges of the electrodes
         with appropriate nonconductive material, such as quartz,
         completes the electrolyte container.

               A heater is provided for the electrolytic solution
15   to elevate the temperature for enhancement of transmission
         of the lithons and deuterons into the lattice by making
         more transmission levels in the palladium deuteride
         lattice available. Initiation of the fusion reaction is
         assisted by elevating the temperature of the electrolyte
20   after loading of the palladium lattice with deuterons to
         achieve a β phase.

               The potential applied across the electrodes is
         defined incrementally in magnitude by the desired
         transmission wavelength of the lithons and deuterons. The
25   rate of the fusion process can be controlled by current
         density within the electrolytic cell. A larger forward
         current will increase power by accelerating tunneling of
         the lithons and deuterons in the lattice, while a reverse
         current will reduce tunneling in the lattice, shutting
30   down the fusion reaction.

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Brief Description of the Drawings

The preferred embodiment of the invention is shown in the drawings.

FIG. 1 is a top cross-sectional view of the electrolytic cell;

FIG. 2 is a pictorial representation of the palladium lattice.

FIG. 3 is a pictorial sectional view of the elements of the electrolytic cell;

FIG. 4 is a pictorial schematic diagram of the reactor core;

FIG. 5 is a schematic diagram of the reactor power plant;

FIG. 6 is a side cross-sectional view of one embodiment of the electrodes of the electrolytic cell employing a plurality of rods of palladium crystal;

FIG. 7 is a representation of the resonant transmission temperature levels for a PdD lattice;

FIG. 8 is a graph of the dimensionless power factor for the palladium deuteride lattice; and,

FIG. 9 is a graph of the temperature rate of change of the power factor.

1   Detailed Description

              Referring to FIG. 1, two electrodes are shown. The
        first electrode 10 comprises a metallic structural member
        12 with a palladium cladding 14. The structural member
5   is configured in a corrugated pattern having multiple
        parallel channels for structural support and fluid cooling
        as will be described in greater detail subsequently. A
        second electrode 16 comprises a structural metallic member
        18 with a cladding 20 of platinum or other nonreactive
10   metal. The second electrode has a complementary shape to
        the first electrode and is mounted in spaced relation to
        the first electrode, creating a contained channel 22
        between the two electrodes. This channel contains an
        electrolytic solution with purified heavy water (D_2O) and
15   lithium deuteroxide (LiOD), or other metal deuteroxide
        which will be described in greater detail subsequently.
        A purity of 99.5% D_2O for the water in the electrolytic
        solution is preferred. Application of an electric
        potential across the two electrodes creates an electric
20   field represented by field lines 24. The field will be
        perpendicular to the surface of each electrode. As is
        typical of electrolytic cells, deuterium gas will be
        evolved at the surface of the cathode, while oxygen gas
        will evolve at the surface of the anode. A spun quartz
25   fiber screen 26, which bisects the channel between the
        electrodes, is employed to prevent mixing of the deuterium
        and oxygen gases as they rise to the top of the channel
        where they are vented into separate collection reservoirs,
        as will be subsequently described.
30   The palladium cladding on the cathode is arranged to
        provide a crystalline lattice of palladium having a
        significant plurality of the individual cells of the
        lattice each oriented with a <1,1,0> direction parallel
        to the electric field at the electrode surface as well as
35   the interior of the lattice. This condition is achieved
        by methods to be described in greater detail subsequently.
        As shown in FIG. 2 for a face centered cubic lattice 210,

1   the individual atoms 212 are joined by covalent bonds 214.
        The direction of view in FIG. 2 is along a <1,1,0>
        direction of the lattice. An electric field perpendicular
        to the electrode surface as shown in FIG. 1 is therefore
5   perpendicular to the interstitial sites in each lattice
        cell through the associated covalent bonds. The
        arrangement of atoms in the lattice provides an octahedral
        interstitial site cornered by the atoms and bounded on
        each side by covalent bonds. Deuterium atoms adsorbed on
10   the surface of the crystal lattice are drawn into the
        interior of the lattice by the electric field. As the
        deuterium atoms enter the electrode's interior they are
        stripped of their electrons. These electrons move into
        the Palladum conduction band and become delocalized from
15   the deuterium nucleus, or deuteron. The deuteron is then
        acted on by the electric field and drawn through the
        lattice until a physical barrier is encountered which
        cannot be tunneled through or diffused around by the
        deuteron.

20   The stripping of the electron from the deuterium atom
        in effect transforms a fermion (the deuterium atom) into
        a boson (the deuteron).

            The potential between the electrodes is established
        to provide an electric field for loading of the lattice
25   having a magnitude to excite the deuteron wavelength for
        transitioning through the covalent bonds of the
        crystalline lattice. For this effect the deuteron
        wavelength is described by the equation: $(\lambda)=4L/n$, where
        L is the distance across the octahedral sites in the
30   lattice (approximately two Angstroms in palladium), and
        n is an odd integer. The addition of an AC ripple signal
        may be employed to tune the field for appropriate deuteron
        wavelength.

            The barrier is placed perpendicular to the electric
35   field, which is the preferred direction of migration of
        the deuterons. In some configurations, the barrier may
        interface with the crystal on more than one plane to block

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1   deuterons driven by components of the electric field
     parallel to more than one of the <1,1,0> directions of the
     lattice.

          The electric field in the electrode itself is
5   determined in part by the physical connection of the
     electrode to the electrical potential.   The electrical
     field in the palladium cladding in the preferred
     embodiment is maintained substantially perpendicular to
     the surface of the cladding by the use of a metallic
10   support having high conductivity and significant depth
     dimension with respect to the cladding.   In addition, as
     the deuterium atoms diffuse into the palladium cladding,
     the resistance of the cladding increases. The net effects
     of the physical geometry of the support and the increased
15   resistance of the palladium cladding is the displacement
     into the metallic support of the majority of current flow
     to the potential. Consequently, the electric field in the
     palladium cladding remains essentially perpendicular to
     the surface of the electrode and the cladding.

20   If enhancement of the direction of the electric field
     in the cladding is required, strips of insulator may be
     added to the surface of the palladium cladding, extending
     into the cladding perpendicular to the surface and to the
     direction of net current flow to the potential.
25   Channeling of current perpendicular to the surface
     accomplished by the insulating strips enhances the field
     perpendicular to the surface.

          An embodiment of this form is shown in FIG. 6 in
     which long single crystals 610 are laminated between
30   insulating strips 612 onto a polycrystalline cladding 614.
     The single crystals have a <1,1,0> axis parallel to the
     electric field which is forced to remain in a direction
     perpendicular to the electrode surface all the way through
     the single crystal.

35   These long single crystals may be grown using a
     floating zone electron beam method. Polycrystalline rods
     of 4 - 5 mm in diameter are bombarded with an electron

1   beam in a vacuum environment of 10^{-5} to 10^{-6} Torr. The
      beam melts a region of the rod approximately equal to the
      diameter in length. The heated section of the rod
      recrystallizes as a single crystal. The rod is then
5   advanced and a new length bombarded by the beam similar
      to a zone refining process. Details of the process may
      be found in Pamplin, B.R., _Crystal Growth_, Pergamon Press
      (1975) PP 140 -142. Impurities are evaporated during this
      process, further enhancing the crystal.
10   The polycrystalline cladding in the embodiment shown
      in FIG. 6 is silver or other nonreactive metal having a
      higher thermal conductivity than palladium and a smaller
      crystalline structure to provide a deuteron diffusion
      barrier.
15   In each of the embodiments described, the structural
      member provides the electrical contact in addition to a
      barrier to diffusion and tunneling of the deuterons in the
      palladium cladding perpendicular to the surface of the
      electrode. As previously described, the electric field
20   direction in the cladding layer is substantially
      perpendicular to the surface of the layer, resulting in
      the structural support being perpendicular to the field
      to provide an effective barrier for the deuterons.
           Referring now to FIG. 3 the preferred configuration
25   of the electrodes is suitable to provide a self-contained
      electrolytic cell. The corrugated shape of the cathode
      10 and complementary shape of the anode 16 when placed in
      spaced relation provide two sides of an enclosure for the
      heavy water electrolyte of the cell. Sealing at the
30   peripheral extremities of the electrodes may be
      accomplished by a insulating quartz cap 310 employing
      quartz to metal seals 312 at the cathode and anode.
      Similar insulating quartz caps may be employed at the
      upper and lower boundaries of the electrodes with
35   appropriate connections for introducing the electrolytes
      and withdrawing the evolved gases.

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1   As shown schematically in FIG. 4 multiple cells 410
        may be placed in a common pressure vessel 412.   The
        electrolyte is supplied to each of the cells through
        connection 414.   Deuterium and oxygen gas evolved at the
5   surfaces of the electrodes in each cell are scavenged
        through connections 416 and 418, respectively.   As
        previously described with respect to FIG. 1, a spun quartz
        fiber screen or other appropriate device may be employed
        to prevent mixing of the deuterium and oxygen gases in the
10   electrolytic cells.

        Coolant is introduced to the pressure vessel at
        connection 420 and circulated through the channels formed
        by the electrodes external to the electrolytic cell.
        Withdrawal of the circulating coolant is accomplished at
15   connection 422.   In the embodiment shown high purity
        ordinary water (H_2O) is used as the coolant. Appropriate
        corrosion protection steps for the structural members of
        the electrodes exposed to the coolant must be employed to
        prevent degradation of the electrodes.

20   The circulating coolant provides the heat exchange
        medium for withdrawing energy from the reactor which is
        created by fusion in the palladium reactor lattices of the
        cathodes in the electrolytic cells.   An embodiment
        employing standard steam plant operating parameters
25   provides an operating temperature of 650°C. This results
        a factor of approximately two for safety margin to the
        melting temperatures of materials employed in the
        electrolytic cells and reactor pressure vessels (steel
        1600°C, nickel 1455°C, palladium 1549°C, platinum 1773°C,
30   copper 1100°C).

        Operation at 650°C requires pressurization above
        2200psi to prevent boiling in the system.   The coolant
        loop in the reactor and the heavy water electrolyte are
        therefore maintained above 2200psi.

35   FIG. 5 provides a schematic for an embodiment of a
        power generation system employing the reactor of FIG. 4
        and a dual coolant loop power generation system.   A heavy

1   water electrolyte tank 510 stores the electrolyte which
      is pumped to the electrolytic cells through a first feed
      pump 512 to the pressure vessel. The evolved oxygen and
      deuterium gas from the electrolytic cells are stored in
5   tanks 514 and 516, respectively. Liquefaction of the
      gases may be employed to reduce storage volume. The
      primary coolant loop provides cooling water through a
      second pump 520 to the pressure vessel. Coolant exiting
      the pressure vessel is routed through a heat exchanger 522
10   and returned to the pump 520. A secondary coolant loop
      employing water or other appropriate coolant receives heat
      in the heat exchanger to generate power in the turbine 524
      after which it is condensed in condenser 526 and returned
      to the heat exchanger by a third pump 528.

15   The present invention also controls the temperature
      of the electrolytic solution. The temperature
      relationship

$$T_n = (2n+1)^2 h^2 / 32mkL^2$$

20   provides a basis for hypothesizing the transmission
      resonance level spectrum for a palladium deuteride (PdD)
      lattice. From the experimental evidence of Pons and
      Fleischmann previously described, transmission resonance
25   is present at room temperature (293K). By solving for the
      well width for $T_n = 293k$ we find

$$L_n = (2n+1)(0.349\text{Å})(243K/293K)^{1/2}$$
$$= (2n+1)(0.318\text{Å})$$

30   Therefore, for integers 0,1,2,3,4, etc. the following well
      widths are defined

          0.318Å, 0.953Å, 1.59Å, 2.22Å, 2.86Å, etc.

35   The lattice parameter for Pd in the α phase is well known
      to be 3.89Å. It is also known that the lattice undergoes

1   a uniform 11% expansion to reach the β phase. Therefore,
      the new lattice parameter is given by $3.89\text{Å} \times (1.11)^{1/3}$.
      The separation of two deuterons residing at neighboring
      octahedral interstitial sites is the value of the lattice
5   parameter divided by $(2)^{1/2}$ or 2.85Å.
            Selecting the width of the a well formed by the
      ascending Coulomb barriers of neighboring deuterons in the
      lattice as 2.86Å a temperature level scheme for
      transmission resonance levels may be obtained for a
10   deuterium loaded β phase palladium lattice with deuterons
      as the diffusing particles (diffusons).

$$T_n = (2n+1)^2 (27K)(1.047\text{Å}/2.86\text{Å})^2$$
$$= (2n+1)^2 (3.62K)$$

15
      FIG. 7 portrays this level scheme.
            A temperature width, ΔT_n, is present at each level.
      ΔT_n is associated with the variation in the well width
      due to thermal vibration. This may be characterized as
20   phonon exchange between the deuterons responsible for the
      Coulomb barrier wells and the metal lattice.   This
      variation, ΔL, in the well width due to vibration from
      the level T_n may be estimated by

25                  $$(1/2)m\ \omega^2 (\Delta L)^2 = (1/2)kT$$

      therefore,

                    $$\Delta L = (kT/m\ \omega^2)^{1/2}.$$

30
   Then,

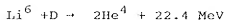 $$\Delta T_n = 2(\Delta L/L)T_n.$$

35   These level widths provide transmission bands for
      propagation of the deuterons in the lattice. Transitions
      via phonon exchange with the lattice would become

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1   significant whenever the thermal energy kT associated with
        an "average" phonon becomes of the order of kT_n, i.e. when
        $T \approx T_n$. Neutron emissions may be created by transitions of
        diffusing deuterons between levels. The burst nature of
5   these emissions may associated with the boson nature of
        neutrons since the symmetric wave function gives bosons
        the tendency to be "gregarious".

            The deuterium reactions in the lattice may be

10                          $D + D \rightarrow T + p$

                            $D + D \rightarrow He^3 + n$
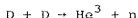
        The following nuclear reactions may also be catalyzed from
15   the system using the LiOD and heavy water electrolyte via
        the transmission resonances within the lattice:

                            $T + D \rightarrow He^4 + n$

20                          $He^3 + D \rightarrow He^4 + p$

                        $Li^6 + D \rightarrow 2He^4 + 22.4 \ MeV$

        Reactions of Li^7 to produce tritium may also be present.
25   The Li^6 - on - a - deuteron reaction to produce He^4
        is hypothesized as the primary energy producing reaction
        in the present invention. Again solving for the well
        width in the lattice, now for Li^6 diffusons in a PdD
        lattice, we see

30
                        $L_n = (2n+1)(0.1838Å)$

        This generates widths of

35   0.18Å, 0.55Å, 0.92Å, 1.29Å, 1.65Å,

                    2.02Å, 2.39Å, 2.76Å, 3.12Å, etc.

Again employing the width closest to that of 2.85Å characteristic of the PdD lattice, 2.76Å, we obtain

$$T_n = (2n+1)^2 (1.303K)$$

resulting in levels of

1.3K, 11.7K, 32.6K, 63.8K, 105.5K, 157.7K, 220.2K, 293.2K, 376.6K, etc.

For Li^7 diffusons within the PdD lattice we find

$$L_n = (2n+1)(0.1702Å)$$

resulting in

$$L = 2.89Å$$

leading to a result for the transmissions levels temperatures of

$$T_n = (2n+1)^2 (1.0145K)$$

with transmission levels of

1.0K, 9.1K, 25.4K, 49.7K, 82.2K, 122.8K, 171.5K, 228.3K, 293.2K, 366.2K, etc.

The presence of a transmission resonance level at 293.2K (20C) or room temperature in the deuteron, Li^6, and Li^7 transmission level structures and numerous transition levels below room temperature supports the presence of heat producing reactions in a room temperature system. Increasing the temperature of the electrolytic solution shifts the Boltzmann distribution for the diffusons to higher energies. This gives more overlap with the higher

                                  -18-

1   order (greater n) transmission levels, which also have
    more of a thermal width. This enhances the probability
    of transmission of the diffusons with a consequent
    enhancement for nuclear reactions.

5   The tunneling process ordinarily associated with a
    cold fusion reaction is sensitive to the mass of the
    tunneling particle. For example, R. Bush and R. Eagleton
    in "Cold Nuclear Fusion: A Hypothetical Model to Probe an
    Elusive Phenomenon", _Journal of Fusion Energy_, accepted

10 for publication August 1989, show that the transmissivity
    for cold fusion not involving a metal lattice is given
    approximately by

$$T = \exp\{-\alpha(m/E)^{1/2}\}$$

15 where α is a constant, m is the mass of the tunneling
    particle, and E is the energy of the particle incident
    upon the Coulomb barrier. For particles of equal energy
    E, the probability for tunneling decreases strongly as the

20 mass m increases. In contrast, cold fusion within a metal
    lattice such as the palladium deuteride in the present
    invention can actually increase as mass increases. This
    is clear from the equation for the de Broglie wavelength
    of the diffusing particle

25
$$\lambda = h/(2mE)^{1/2}$$

    since for particles of equal energy, E, λ is smallest for
    the particle of largest mass. The advantage of smaller

30 λ is that there are more ways in which the transmission
    resonance condition can be satisfied. The formula for T_n
    specifying the resonant transmission levels also shows
    this, since mass m occurs in the denominator. Based on
    this, nuclear reactions in the PdD lattice involving Li^6

35 and Li^7 may predominate over those involving deuterons.
    (Additionally, Li^6 may predominate over Li^7 since the
    former are bosons while the latter are fermions.)

-19-

1   Similar calculations may be made for alternate
metallic lattices such as titanium which may be used for
electrode materials. Titanium deuteride as a lattice does
not provide the large number of transmission resonance
5   levels present in palladium deuteride for the same
temperature with deuterons as the diffusons. However,
structural or other considerations may make the use of a
titanium lattice in the cathode desireable with an
alternate diffuson.

10   Enhancement of the transmission resonance levels
available for the deuterons is accomplished in the present
invention by heating the electrolyte entering the reactor
in a feed water heater 530 as shown in FIG.5. The heater
is operated to achieve electrolyte temperatures of 500 to
15   600 C to provide the greatest number of transmission
resonance levels for the deuterium and Li^6 in the
electrolyte to be transmitted through the lattice.

Electrical resistance heating, fuel fired heat
exchangers or other methods may be used for the feedwater
20   heater. Recombination of the O_2 and D_2 gases produced by
the cell may be used for the fuel heat source or as an
energy supplement for the feedwater heater by returning
the gases to the heater shown schematically by lines 532
and 534 in FIG. 5.

25   The use of high purity Li^6 for the LiOD in the
electrolyte provides a "clean" reactor avoiding production
of tritium from Li^7. An optimum electrolytic solution
having .1 to .5 molar LiOD with a purity of 99.5% for Li^6
is used.

30   A power factor P(T) is used to compare the
transmission aspects of the reactions in the present
invention. P(T) is proportional to the total number of
diffusing deuterons and therefore is equal to the number
of deuterons in metastable states. The population of
35   deuterons in the nth state is proportional to the
Boltzmann factor therefore

1
$$P(T) = \Sigma \exp(-E_n/kT)$$
$$= \Sigma \exp(-T_n/T).$$

The value of P(T) increases with increasing
5   temperature T due to the negative exponentials. A
positive temperature coefficient for the cold fusion
process is therefore present. A plot of the power factor
for palladium deuteride is shown in FIG. 8.

SImilarly, if it is assumed that all other aspects
10 such as nuclear cross-sections remain the same at
different temperatures the rate of change of the power
factor with temperature follows directly

$$dP/dT = T^{-2} [\Sigma T_n \exp(-T_n/T)].$$

15
A plot of dP/dT is shown in FIG. 9 for palladium
deuteride.

The rate of change of the dimensionless power factor
with temperature has an inverse square dependence upon the
20 temperature. Similar calculations may be made for a
Titanium deuteride lattice.

Near the surface of the electrode the diffusion of
the deuterons (and other particles) in the lattice may be
described in terms of the Maxwell velocity distribution
25 for a temperature T.

$$dN(v)/dv = T^{-3/2} v^2 \exp(-mv^2/2kT)$$

where N is the number of diffusing particles with velocity
30 v. A velocity v_n corresponding to a transmission resonance
is given by

$$v_n = h/m \lambda$$

where the de Broglie wavelength λ satisfies the resonance
35 condition. The number of diffusing deuterons having this
velocity corresponding to a particular value of n is

1   proportional to the area under the curve of $dN(v)/dv$
     versus v for the value $v=v_n$. This, of course, is zero.
     Therefore, it is the phonon exchange between the lattice
     and the deuterons whose Coulomb barriers form the wells,
5   that results in a thermal width for the resonance
     transmission levels, thus providing candidate deuterons
     for transmission. The velocity width Δv_n corresponding
     to the ΔL is given by

10                   $$\Delta v_n = 2 \ \Delta L m v_n^2/h.$$

     The relation of v_n to the nth order transmission resonance
     level is

15                       $$m v_n^2/2 = k T_n.$$

     Taking the thermal width into account for the transmission
     resonance velocity, the number of candidate deuterons for
20   resonant transmission is now proportional to the area
     under the curve of $dN(v)/dv$ versus v between $v_n - (\Delta v_n)/2$
     and $v_n + (\Delta v_n)/2$. This can be approximated by

         $$\{[dN(v)/dv]_v \ \Delta v_n\} \propto T^{-1} T_n^{3/2} \exp(-T_n/T)$$
         $$\propto T^{-3/2} T_n^{1/2} \ \Delta T_n \exp(-T_n/T)$$

25   Since $\{[dN(v)/dv]_v \ \Delta v_n\}$ has a maximum when $T = T_n$
     setting the derivative with respect to the temperature T_n
     equal to zero will provide a maximum:

30               $$d/dT[T^{-1} T_n^{3/2} \exp(-T_n/T)] = 0$$

     Solving this equation shows the maximum at

                         $$T_{max} = T_n.$$

35   This also corresponds to the most probable velocity for
     the Maxwell velocity distribution. This implies that

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1   neutron bursts may be produced by deuterons with
      correlated velocities with the maximum of the velocity
      distribution corresponding to a transmission level, v_n.
          This allows a power factor of

5

$$P(T) = T^{-1} \Sigma T_n^{3/2} \exp(-T_n/T)$$

      for comparing powers at different temperatures for a
      particular lattice (e.g. PdD). Thus, for Li^6 lithons as
10   diffusons in a PdD lattice it can be shown that the power
      yield would be three times a great at 600 K as at 293 K.
      Nuclear factors should enhance this.
          As a second embodiment, the growth of dendrites or
      sintering of palladium grain crystals on the surface of
15   the cathode is provided to enhance a surface reaction. In
      this embodiment, the structural support of the electrode
      is first clad with a thin film of polycrystalline
      palladium foil, or other conductive nonreactive material,
      by electroplating, vapor-deposition or other technique,
20   and a layer of single crystal palladium grains is sintered
      to the surface of the palladium cladding. Annealing of
      the sintered grains is accomplished to create essentially
      a single crystal in each grain.
          A temperature coefficient based on this power factor
25   is also positive., and assuming other conditions to be the
      same, more power is yielded at higher temperatures. The
      Maxwell velocity distribution is shifted by increasing
      temperature for higher values of v thereby allowing more
      transmission levels, v_n, to make a significant
30   contribution. The thermal width, ΔT_n, of a transmission
      level is proportional to both n and $T^{1/2}$.
          The present invention provides opportunity for cold
      fusion by loading a metal deuteride lattice and providing
      diffusing particles, deuterons and lithons, with energies
35   overlapping the transmission resonance levels defined by
      T_n. Loading of the lattice is enhanced by arrangement of
      the crystal lattice parallel to the electric field between

-23-

the electrodes and providing a barrier to prevent
diffusion completely through the lattice as previously
described. Loading of the lattice is accomplished with
a current density of about 10 - 50 mA/cm^2 to create a β
phase by loading deuterons in the interstitial sites in
the lattice. Achieving stoichiometry of at least .7 in
the reactive portion of the lattice is desirable in the
loading.

Loading is conducted with the lattice and electrolyte
at room temperature or lower. After loading is complete,
the probability of fusion reaction is enhanced by
increasing the electrolyte temperature using the feed
water heater. "Bumping" of the current between the
electrodes may be employed to assist in starting the
resonant transmission of particles into the loaded
lattice. The AC ripple previously described will be
sufficient in most applications.

As previously described control of the fusion
reaction in the individual cells is accomplished by
varying the current density in the electrodes thereby
controlling migration of deuterons and lithons through the
lattice to the barrier points. Variation in the
electrolyte temperature by increasing or decreasing heat
input through the feed water heater is also employed to
control the reaction.

Operation of the reactor will eventually "poison" the
electrodes with He^4 in the lattice. Further, the lattice
cites in which fusion has taken place and those
surrounding will be damaged due to the production of heat.
The electrodes in the reactor must then be refurbished or
replaced.

In operation, application of electric potential to
the reactor cells could be alternated for periodic
intervals to allow annealing of the crystalline lattice
or reformation of the crystal in the sites damaged by
fusion by heating from adjacent cells to effectuate "self
repair". If electrode annealing is too slow at 650 C

1   design of the operating temperature and pressure of the
     reactor may be correspondingly increased as required
     within limits imposed by the structural materials.

          Reduction of pressure of the electrolyte in
5   combination with heating will provide some limited removal
     of the He^4 in the lattice. It should be noted that
     removal of the reactor electrodes and recovery of the He^4
     present will provide significant cost benefit.

          As alternative embodiments to that described
10   previously, the reactor lattice may be arranged on a
     symmetrical electrode such as a sphere or cube where all
     surfaces of the electrode exposed to the electrolyte are
     perpendicular to the electric field and the field inside
     the electrode is aligned essentially through the geometric
15   centroid of the electrode. Those skilled in the art will
     recognize fabrication and electrical connection techniques
     such as an insulated probe electrically connected at the
     tip with the geometric centroid of the electrode to
     provide the potential to the electrode. This arrangement
20   of all electric field lines radiating from the center of
     the electrode provides a self-induced "boundary" at the
     center of the electrode preventing the deuterons from
     exiting the electrode. Practical heat removal in this
     configuration may prove difficult.

25   It should further be noted that the reactor design
     of the present invention is compatible with the structural
     components of existing fission reactor designs. The
     fission cores in these reactors could be replaced with the
     cold fusion electrode systems of the present invention as
30   a retro-fit significantly reducing capital cost for
     building such fusion reactors and providing a beneficial
     use for decommissioned fission reactors in providing clean
     power generation.

          Having now described the invention in detail as
35   required by the patent statutes, those skilled in the art
     will recognize potential modifications to the geometry and
     materials employed in the electrodes including the

1   crystalline lattices and possible power generating plant
     configurations without departing from the scope and intent
     of the invention as described in the following claims.

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1   WHAT IS CLAIMED IS:

       1.   An apparatus for producing heat energy through
     cold fusion comprising:
5   a crystalline reactor lattice having octahedral
     interstitial sites defined by atoms of the lattice, and
     the atoms having parallel bonds on opposite sides of the
     octahedral sites;
                 a means for maintaining an electrolytic solution
10   including heavy water and metal deuteroxide as a source
     of deuterons and metal ions for diffusing particles in
     communication with a surface of the crystalline reactor;
                 means   for   generating   an   electric   field
     perpendicular   to   any   pair   of   parallel   bonds   of   a
15   significant   plurality   of   the   interstitial   sites,   the
     electric field having a magnitude causing the average
     wavelength of the diffusing particles, between collisions,
     to be equal to a transmission resonance wavelength;
                 means for creating a boundary which blocks the
20   lattice perpendicular to the electric field in the lattice
     at a location of lower electric potential than the surface
     of the crystalline reactor; and,
                 means for heating the electrolytic solution.

25   2.   An apparatus as defined in claim 1 wherein the
     crystalline   reactor   lattice   comprises   a   plurality   of
     single metallic crystals of face centered cubic structure
     oriented   in   any $\langle 1,1,0 \rangle$ direction   with   respect   to   a
     surface of the crystal.
30
       3.   An apparatus as defined in claim 2 wherein the
     metallic crystal is palladium.

       4.   An apparatus as defined in claim 3 wherein the
35   metal deuteroxide is lithium deuteroxide and the metal
     ions are lithons.

5.   An apparatus as defined in claim 3 further comprising a structural member having a polycrystalline cladding to which the reactor lattice is bonded.

6.   An apparatus as defined in claim 5 wherein the lattice comprises single crystal grains of palladium sintered to the polycrystalline cladding.

7.   An apparatus as defined in claim 4 wherein the means for generating an electric field comprises:

a cathode, the reactor lattice being an integral portion of the cathode;

an anode immersed in the electrolytic solution, and,

an electric potential connected between the anode and cathode.

8.   An apparatus as defined in claim 7 wherein the electric potential is adjustable.

9.   An apparatus for producing heat energy from cold fusion of diffusing particles comprising:

an electric potential;

a heavy water and lithium deuteroxide electrolyte bath;

a first electrode connected to the potential and having at least one surface immersed in the bath;

a second electrode connected to the potential having at least one surface, substantially parallel to the surface of the first electrode at all points of tangency, said one surface immersed in the bath thereby completing the circuit and creating an electric field in the bath and the second electrode further having:

a metallic face centered cubic crystalline reactor lattice exposed at the surface of the second electrode, with a substantial plurality of octahedral

1   interstices of the lattice oriented with the <1,1,0>
        direction perpendicular to the surface,

                    a metallic boundary, perpendicular to the
        electric field in the second electrode, at which the
5   lattice terminates thereby preventing further tunneling
        and diffusion by diffusing particles in a direction
        parallel to the electric field, and,

                    a means for controlling the temperature of the
        electrolyte.
10

        10. An apparatus as defined in claim 9 wherein the
        lattice terminates at a metallic boundary on each surface
        not in contact with the electrolyte thereby preventing
        tunneling and diffusion by the deuterons from the lattice.
15

        11. An apparatus as defined in claim 9 wherein the
        electric potential is controllable and reversible.

        12. An apparatus as defined in claim 10 wherein the
20   crystalline reactor lattice comprises a plurality of
        single crystals and the metallic boundary comprises a
        structural member connected to the electric potential and
        further comprising dielectric strips bonded intermediate
        the single crystals to form a laminated lattice, the
25   dielectric strips perpendicular to a direction of primary
        current flow in the structural member.

        13. An apparatus as defined in claim 9 wherein the
        electrolyte contains lithium deuteroxide having a 99.5%
30   purity of Li^6.

        14. An apparatus as defined in claim 13 wherein the
        molality of the lithium deuteroxide in the electrolyte is
        .1 to .5.
35

1   15. A method of producing power by fusion of
diffusing particles with trapped particles in a lattice
comprising the steps of
            fabricating a reactor cell by the steps of
5   forming a plurality of single crystal palladium
rods having a <1,1,0> direction perpendicular to the
surface of the rods,
                mounting the rods to a metallic structural
member to form a first electrode,
10   placing a second electrode in parallel spaced
relation to the first electrode,
                sealing between the adjacent peripheral edges
of the first and second electrodes, and,
                introducing a heavy water and metal deuteroxide
15   electrolyte between the electrodes as a source of
deuterons and metal ions as diffusing particles,
            circulating a coolant around the reactor cell,
            applying an electric potential between the first and
second electrode,
20   controlling the polarity and magnitude of the
electric potential,
            heating the electrolyte, and,
            withdrawing heat energy from the coolant to generate
power.
25
            16. A method as defined in claim 15 wherein the
metal deuteroxide used is lithium deuteroxide and the
metal ions are lithons.

30   17. A method as defined in claim 15 wherein the
heavy water in the electrolytic solution is 99.5% pure.

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-30-

18. A method as defined in claim 15 further comprising the steps of:

installing a plurality of reactor cells in a pressure vessel, and,

alternately applying the electric potential to selected reactor cells to allow annealing of adjacent reactor cells.

19. A method as defined in claim 16 further comprising the step of reducing the pressure of the electrolyte during annealing of reactor cells to extract He^4 contaminant from the electrodes.

20. A method as defined in claim 15 further comprising the step of loading the palladium lattice with deuterons to a stoichiometry of between .7 and 1 prior to heating the electrolyte.

21. A method as defined in claim 20 further comprising the step of providing an AC ripple on the electrode potential to bump the current in initiating a resonant transmission of lithons and deuterons into the lattice.

22. A method for creating a cold fusion reaction in a palladium lattice electrode comprising:

formulating a heavy water electrolytic solution with a molality of .1 to .5 lithium deuteroxide having a 99.5% purity of Li^6 to provide deuterons and lithons as diffusing particles;

immersing the palladium lattice in the electrolytic solution;

introducing an electric field of 10 to 50 mA/cm^2 perpendicular to a <1,1,0> direction in the crystals of the lattice to load the lattice;

1   loading the lattice to a stoichiometry of .7 to
1 with deuterons from the electrolytic solution creating
a β phase in the resulting palladium deuteride lattice;

           heating   the   electrolytic   solution   to   a
5 temperature   exceeding   a   plurality   of   transmission
resonance temperatures for the diffusing particles; and,

           controlling   current   in   the   electrode   and
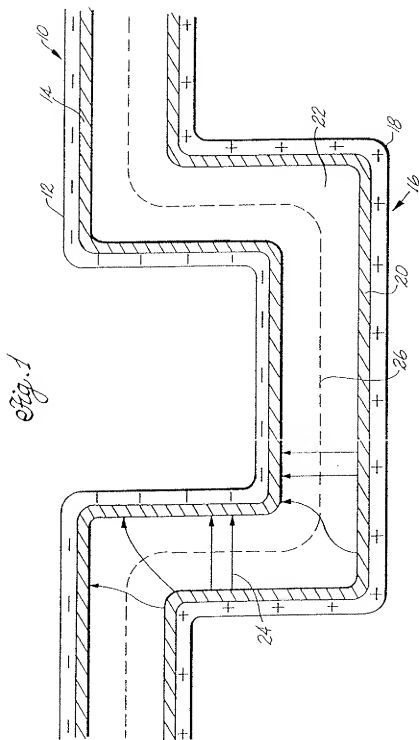temperature of the electrolytic solution to control the
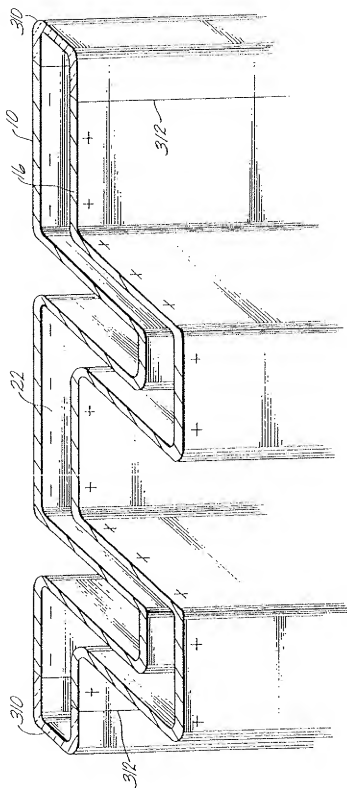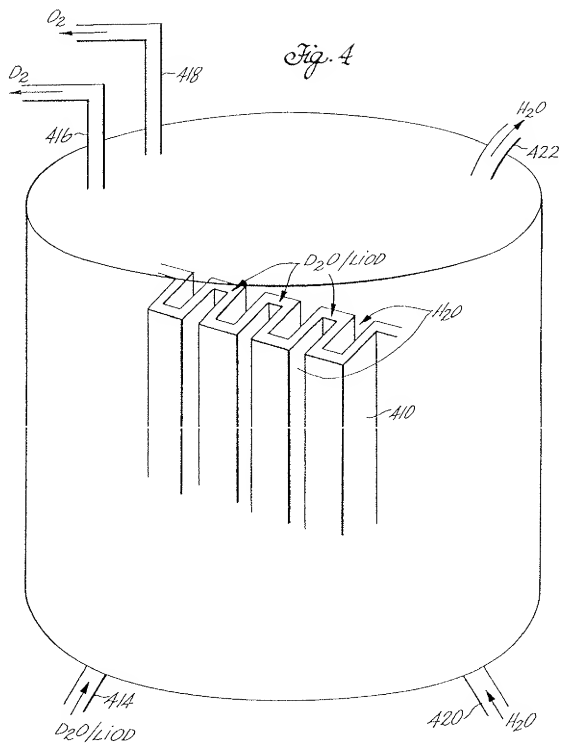fusion reaction.

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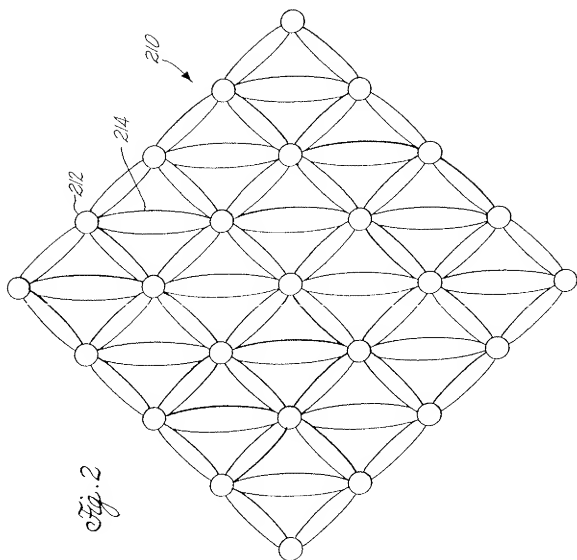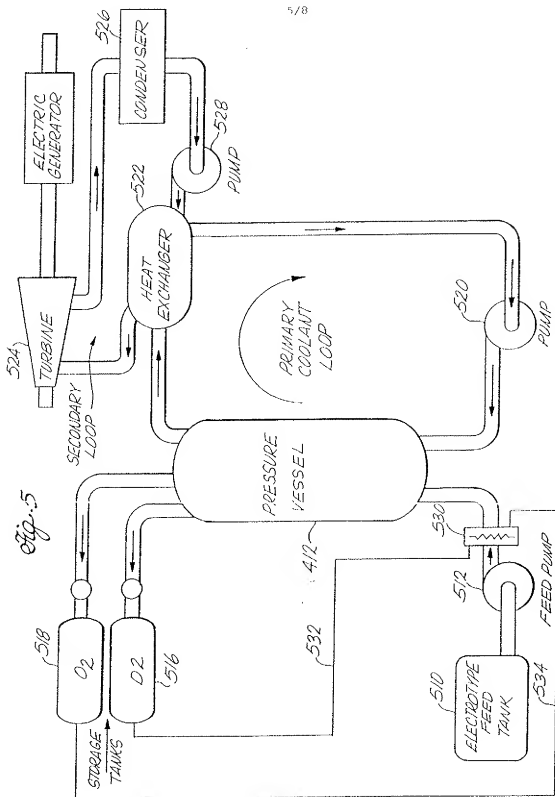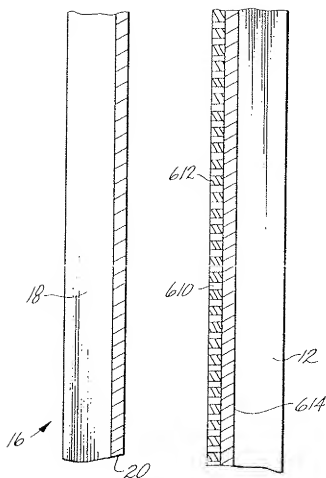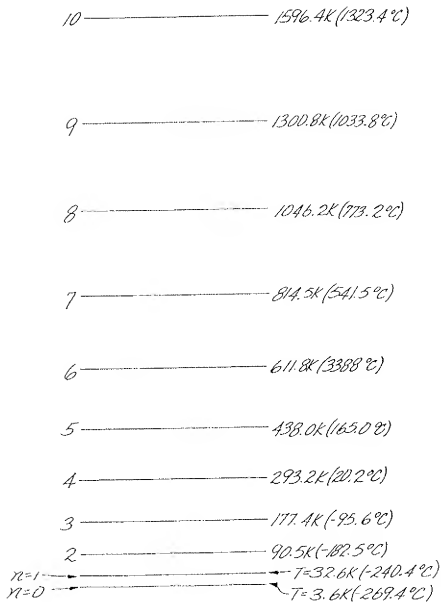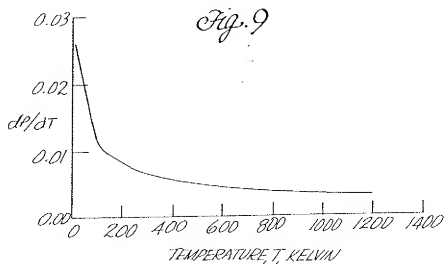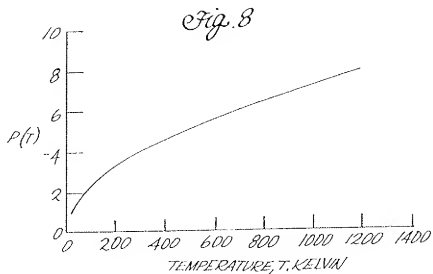
Fig. 1

Fig.2

Fig. 3

Fig. 4

Fig. 5

ELECTRIC GENERATOR

CONDENSER 526

528 PUMP

522 HEAT EXCHANGER

524 TURBINE

SECONDARY LOOP

PRIMARY COOLANT LOOP

520 PUMP

PRESSURE VESSEL

412

530

532

510 ELECTROLYTE FEED TANK

512 FEED PUMP

534

STORAGE TANKS

518 O2

516 O2

Fig. 6

*Fig.*7

10 ——————————— 1596.4K (1323.4°C)

9 ——————————— 1300.8K (1033.8°C)

8 ——————————— 1046.2K (773.2°C)

7 ——————————— 814.5K (541.5°C)

6 ——————————— 611.8K (338.8°C)

5 ——————————— 438.0K (165.0°C)

4 ——————————— 293.2K (20.2°C)

3 ——————————— 177.4K (-95.6°C)

2 ——————————— 90.5K (-182.5°C)

$n=1$ —————— $T=32.6K$ (-240.4°C)

$n=0$ —————— $T=3.6K$ (-269.4°C)

Fig.8

$P(T)$ vs. TEMPERATURE, T, KELVIN

Fig.9

dP/dT vs. TEMPERATURE, T, KELVIN

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): G21B 1/00
U.S.CL.: 376/100

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
U.S.	376/100, 146, 114, 115 423/248, 645, 647.7 420/900, 463, 464, 465 204/129, 290R, 290F, 291, 292, 293, DIG. 8

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched

III. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of Document, with Indication, where appropriate, of the relevant passages	Relevant to Claim No.
Y	Electroanalytical Chemistry, Volume 261, No. 2A, page 301-308, Parsons et al., April 1989.	1-22
Y	"The Palladium Hydrogen System", Academic Press 1967, page 1-180, Lewis; Figure 3.3.	2,3,6,12,15
Y	"The Kinetics of Hydrogen Absorption-Desorption by Metal", Pergamon Press 1981, page 329-343, Pick; page 341, Paragraph 2.	2,9,15,22
Y	US, A, 4,663,006 (YAO ET AL) 05 May 1987, Column 10, line s 54-57; abstract.	18
Y	US, A, 4,373,176 (FINKELSTEIN ET AL) OR February 1983; Column 1, lines 44-51.	21
Y	US, A, 3,455,845 (WICKE ET AL) 15 July 1969; Column 1, lines 47-52; column 3, lines 31-43.	5,6,10
Y	"Determination of the Hydrogen Content of Palladium and Palladium Alloys from Measurements of Electrode Potential and Electrical Resistance", Pergamon Press 1963, Volume 10, page 237-246, Barton et al; page 239, Paragraph 5.	10

* Special categories of cited documents: 10
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the International filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the International filing date but later than the priority date claimed

"T" later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

IV. CERTIFICATION	
Date of the Actual Completion of the International Search 03 APRIL 1991	Date of Mailing of this International Search Report 29 APR 1991
International Searching Authority ISA/US	Signature of Authorized Officer DANIEL WASIL

Form PCT/ISA/210 (second sheet) (May 1986)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE[1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers .... , because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers .... , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [i], specifically:

3. ☐ Claim numbers_____, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING[2]

This International Searching Authority found multiple inventions in this international application as follows:

     See attachment

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☒ No protest accompanied the payment of additional search fees.

Continuation of PCT/ISA/210 item VI
"Observations where unity of invention is lacking"

I.   Apparatus for producing heat energy; (claims 1-14).

II. Method of producing power; (claims 15-21).

III. Method of creating a cold fusion reaction; (claim 22).

The claims of these groups are directed to different inventions which are not so linked as to form a single general inventive concept. The inventions are not linked in operation and perform completely different operations. Note PCT Rule 13 and 37 CFR 1.475.

Within group I there is lack of unity under PCT Rule 13 between the following independent and distinct species :
Ia. The embodiment having a polycrystalline cladding; (claims 1-11, 13, 14).
Ib. The embodiment having dielectric strips bonded intermediate single crystals; (claims 1-4, 7-14).

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
L	Nature, volume 344, page 401-405, 29 March 1990, Salamon et al., cited as casting doubt on inducing nuclear fusion in a catalyst by forcing hydrogen isotopes therein.	1-22
L	ORNL/FTR-3341, page 1-17, 31 July 1989, Cooke; Cited as casting doubt on inducing nuclear fusion in a catalyst by forcing hydrogen isotopes therein, see page 3-5.	1-22